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ABSTRACT

This report summarizes a meeting which was held to explore some of the major issues raised by the current call for science education reform, and to make recommendations regarding what steps should be taken to ensure that the needed improvements in elementary and secondary science will actually be made in schools across the country. Included are discussions of: (1) the science education improvement effort to date; (2) the need for a new conceptual framework for scientific and technological education; (3) science education goals, curricula, and materials; (4) preservice teacher education; (5) inservice teacher education; (6) the role of teachers and supervisors in improving science education; (7) harnessing educational research; (8) organizing for science education improvement; (9) science education improvement and the non-public schools; and (10) the context of science education improvement. Among the recommendations offered are the adoption of a new framework for science education based on scientific and technological literacy for all citizens, systematic efforts to develop model K-12 science curricula which would be fully supportive of the literacy goal, a reappraisal and reform of both pre- and in-service teacher education, and substantial involvement of school building-level educators in bringing about real change. (JN)

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SCIENCE EDUCATION IN THE UNITED STATES: ESSENTIAL STEPS FOR ACHIEVING FUNDAMENTAL IMPROVEMENT

A REPORT
ON A MEETING
OF EDUCATIONAL LEADERS
HOSTED BY
THE EXXON EDUCATION FOUNDATION

JANUARY 17-20, 1984

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Preface

On January 17, 1984 a group of educational leaders assembled in New York City for a two-and-one-half-day discussion of science education hosted by the Exxon Education Foundation. The purpose of the meeting was to define more precisely what actions will be required to achieve the broad-based, sustained improvement in science education called for by several of the recent reports on the status of schooling in America. A majority of the participants were senior officials in major national organizations which represent elements of the educational community that will participate either directly or indirectly in bringing about changes in science education in the years ahead.[1] Several participants were experienced science teachers. The chairperson of the meeting was Dr. Paul DeHart Hurd, Professor Emeritus of Science Education, Stanford University. Dr. Hurd has long been one of the nation's most thoughtful leaders in science education.

Prior to the meeting, a team of science education consultants with diverse backgrounds was asked to identify critical, unresolved issues in the science education improvement debate.[2] Their work provided the starting point for the meeting's discussions.

What follows represents the consensus of the participants. Their respective endorsements of this report reflect their personal views, not those of the organizations with which they are associated.

1. See Appendix I for list of participants.
2. See Appendix II for list of consultants.

Providing a forum in which educational leaders can attempt to sharpen thinking on major issues is an important way in which an organization such as ours can be of assistance to the educational system. Consequently, even though elementary and secondary school science education is not a primary programmatic focus of the Exxon Education Foundation, we are pleased to have convened this meeting. We believe that the conclusions of the group should be of interest to all those concerned with furthering the improvement of science education in the United States.

Robert L. Payton
President
Exxon Education Foundation

Executive Summary

The majority of recent national reports on education in the United States has identified science as an area of pressing concern. Science is neglected in the elementary schools and rejected by a large proportion of students in the upper grades. Student achievement has been declining for more than a decade. These conditions are compounded by a shortage of qualified science teachers.

The concern expressed in the national reports is heightened by the sense that students of today and tomorrow will need a much different, more extensive science education than elementary and secondary schools have provided in the past. Historically, science education has been primarily concerned with insuring that a sufficient number of students in each generation would be prepared for the pursuit of scientific and engineering studies on the college level. However, there is a growing feeling that the scientific and technological dimensions of our society, government, and economy are now sufficiently extensive that virtually *all* citizens must become scientifically and technologically "literate."

The purpose of the meeting of educational leaders hosted by the Exxon Education Foundation was to explore some of the major issues raised by the current call for science education reform, and to make recommendations regarding what steps should be taken to ensure that the needed improvements in elementary and secondary (K-12) science will actually be made in schools across the country.

The participants agreed that the first step should be the development of a new conceptual framework for science education which reflects the scientific and technological dimensions of the world in which our young people will reside. The group agreed that the task should be undertaken by scientists, engineers, and educators working in collaboration.

The participants also agreed that a reformulation of science education of this kind would rapidly lead to the need for model articulated K-12 science curri-

cula and associated new instructional strategies and materials. It also would require the concomitant development of new approaches to preservice and inservice training for teachers. Finally, it would demand more effective use of relevant educational research.

Given the country's decentralized approach to education, the group concluded that it will be difficult to undertake a fundamental reappraisal and reengineering of an area as complicated as science education in a manner that will lead to real changes at the classroom level in *most* schools. In order to improve significantly the prospects of achieving a broad-based reform, the participants recommended that a *consortium* be established composed of (but not limited to) national education organizations of the kind represented at the meeting as well as of the scientific and engineering professions. This consortium would play a leadership and coordinating role for the reform effort. Its initial responsibility would be to undertake an evaluation of the proposed scientific and technological literacy approach to K-12 science. The consortium would be designed to remain in existence for several years to ensure that the necessary commitment to science education reform is sustained.

Central to the consortial approach is the recognition that change in education must involve many actors associated with K-12 schooling, including university faculties, chief state school officers, state and local school boards, superintendents, curriculum specialists, building-level administrators and supervisors, teachers and parents, and the scientific and engineering communities. Previous reform efforts have not adequately recognized the importance of involving all these groups—especially the *teachers*—from the beginning. The participants concluded that this is a shortcoming which must be avoided if the current improvement effort is to succeed. The group concluded that a consortial approach is an important means of ensuring their full involvement.

Introduction: The Science Education Improvement Effort to Date

A common conclusion of many of the recent national reports on the status of K-12 schooling in the United States is that several subjects, including science, must be improved substantially if the educational needs of our young people and the country are to be met. The National Science Board (NSB) Commission on Precollege Mathematics, Science and Technology report, *Educating Americans for the 21st Century*, provides the most specific guidance on the direction that science education improvement efforts should take. The NSB Commission emphasizes two key points:

(1) Science education must be modified to include a substantial technological component.

(2) "Scientific and technological literacy" should be established as one of the primary academic goals of K-12 education for *all* students.

These two recommendations stand in marked contrast to the approach to science education supported by the National Science Foundation (NSF) and accepted by the educational community from 1950 until about 1980. During that period, attention was focused almost exclusively on the educational needs of students aspiring to scientific and engineering careers, and technology was deliberately downplayed.

The call for science education improvement comes at a time when school science is beset by many problems, including declining science achievement scores for 17-year-olds, declining high school science enrollments, virtual absence of science in the elementary schools and a shortage of science instructors with a rich, current educational background in the subjects they are teaching.

To foster a major improvement in K-12 science education, the several reports propose a variety of changes, each of which falls within one of three areas:

(1) those that would lead to more science instruction in the general education core for each student;

(2) those (following the NSB Commission's lead) that would promote a different kind of science education—different in goals, subject matter and content—from what is generally now provided by most schools; and

(3) those that would place greater emphasis on intellectual excellence in the use of scientific and technological education.

The national reports have stimulated much discussion and considerable action—particularly on the part of state governments—directed at science education improvement. So far, state action has tended to focus on things that can be mandated by legislation or regulation. For example, by early 1984, thirty-five states had increased the number of science courses required for graduation from high school to two years or more. Some states also had raised the scores required on achievement tests for students to receive their high school diplomas. Other states had mandated that science teachers must pass proficiency tests to obtain or retain certification. Some states had taken steps to increase the number of science courses that college students preparing to become teachers have to complete before they can be certified.

In contrast, little has been done to date by the states to promote fundamental reappraisal of K-12 science courses and/or teacher preparation programs at state colleges and universities from the perspective of scientific and technological literacy. This is not surprising, since mandating-type actions are more consistent with the standard-setting responsibilities of state government. They are also much easier to undertake.

The Need for a New Conceptual Framework for Scientific and Technological Education

The meeting participants were very sympathetic to the basic premise in the national reports that substantial changes in K-12 science education are needed. However, they concluded that it is not yet clear *what* an improved science education really would be, *how* it could be most effectively provided, or *what* actual benefits to individuals and

society could realistically be expected. For this reason, they expressed some doubts about the initial heavy reliance on mandating more coursework and higher performance standards in traditional courses. Given the evidence that many students often have found existing science offerings to be unrewarding, they felt that "more of the same" via the mandating approach might lead to little improvement in the absence of a fundamental reappraisal of K-12 science education.

In this regard, the participants believed that the NSB Commission's call for scientific and technological literacy for all citizens might hold the key to the reconsideration of science education that the current reform movement requires. Although participants felt that "scientific and technological literacy" in its present form is more of a slogan than a well-developed, unifying concept, it is a notion which suggests two important reasons why a more extensive, reformulated K-12 science program is needed:

(1) Scientific and technological understanding is a key to adjusting to and participating in a world that will continue to change rapidly technologically for the foreseeable future.

(2) Because these changes occur in all realms of life—work, civic affairs and personal—the case that such education is relevant to virtually all Americans seems compelling.

From this perspective, scientific and technological literacy seems to call for a future-oriented science curriculum. Such a curriculum would provide students with basic concepts and the intellectual tools, in an applications context, relevant to their lives.

The interconnections among science, technology and human affairs also appear to demand a science program more interdisciplinary in nature, with linkages *among* the sciences, and *between* the sciences and the humanities. Consequently, the participants concluded that the science curriculum now found in most schools is probably much too narrow in scope and too bound to traditional disciplines to meet the requirements of true scientific and technological literacy.

To the extent that there is a conceptual framework that now identifies science education, its major features seem to be:

(1) courses organized to represent the structures of discrete scientific disciplines, supported by professional information selected to illustrate the cumulative state of knowledge and theories of each discipline as viewed by researchers;

(2) inquiry skills taught in the context of how new scientific information is presumed to have been discovered;

(3) virtual absence of instruction directed at technological and engineering concepts or methods of thinking in these areas; and

(4) general avoidance of questions of ethics and values raised by science and technology except in the context of the professional conduct of scientists (e.g. intellectual honesty and falsification of data).

This framework for science education in America is rooted in over 200 years of tradition. The recommendations of the NSB and other national reports for restructuring science education are clearly in contrast with this traditional approach.

Given this situation, the participants concluded that an essential next step in the science education improvement effort is to develop more fully the notion of scientific and technological literacy through a process that will allow it to be tested rigorously for cultural, scientific, and technological validity and learnability. Assuming that the results were positive, scientific and technological literacy would then become the basis for identifying which concepts, intellectual skills, and types of applications should be taught in K-12 science education.

This substantial undertaking would require unprecedented systematic, goal-directed collaboration among scientists and engineers, science teachers, and other educators. It would also entail considerable participation by sociologists, philosophers of science and technology, and others who can inform and/or help provide legitimacy to the development of the new framework.

It could take several years for such a dialogue to produce a complete conceptual framework, along with supporting documentation and educational options, that is fully supported by the diverse participants in the process. Moreover, if the future-oriented conception of science education is correct, there may actually be no "final" statement of the framework. Rather, it could become the subject of continuing discussion and change, reflecting new developments in science and technology and their impact upon human affairs.

The meeting's participants felt that the reconstruction of the school science curriculum could begin before the full formulation of the new conceptual framework. Each of the national reports have to some degree identified educational attributes that their authors believe would improve the quality of science education. Broadly, their recommendations show remarkable agreement, enough in the participants' view to justify the development of prototype curricula and instructional materials for testing with classes. For the elementary school, the immediate task is one of restoring a balanced curriculum with adequate daily time for science.

Science Education Goals, Curricula and Materials

If a new framework for science education is to be adopted based on scientific and technological literacy for all citizens, the participants concluded that systematic efforts must be undertaken to develop model K-12 science curricula which would be fully supportive of the literacy objective.

The initial task would be to determine what is worth knowing about science and technology that has significance for most people. This would entail selecting appropriate subject matter from all that has been learned in the natural sciences and technology that might reasonably be taught to children and adolescents in the time available. (If the recommendations of the various national reports on schooling are followed, science would be taught every day at all grade levels from kindergarten through grade ten as

a requirement, a total of approximately 2,000 hours. Advanced science or preprofessional courses for the interested student would be offered during the last two years of high school.)

The curriculum reform effort would include the identification of the cognitive skills essential to the optimal use of scientific and technological knowledge in civic and personal affairs. In the present science curriculum the cognitive skills are limited in the main to those associated with scientific inquiry. In any new curriculum, the range of skills probably would need to be extended to include those essential for coping with certain types of science/technology issues common to most social settings and to most people's lives. This approach also would require students to work with certain non-science-specific notions such as ethical judgment, probabilistic reasoning, and risk assessment in a scientific/technological context.

An overall objective of any new science curriculum would be to enable students to become better problem-solvers and decision-makers through the use of science-based information and skills. Consequently, it is important to recognize that scientific and technological literacy is an operational objective and exists only in the context of intepreting and seeking wise solutions to problems.

Participants recognized that determining how a curriculum should be organized vertically through the grades and within specific courses is essential. Traditionally, the organization of the science curriculum in most school systems has tracked closely the hierarchy and cumulative development of the basic sciences. This organization is described as a "spiral curriculum," with courses designed to portray the "structure of disciplines" and to provide opportunities for students to learn "inquiry skills used by scientists." The subject matter of these courses is chosen in part for its professional significance to researchers.

The participants believed that qualitative changes proposed in the national studies of education would require a science curriculum that goes beyond the

limitations imposed by specific disciplines. The combining of information from the sciences and technology with the goal of optimizing its application to human affairs would require a cross-disciplinary perspective on science education.

The development of model science curricula designed for all students should be carried out with an awareness that it is at least a ten-year program. What is sought is a coherent curriculum of science and technology fostering increasingly higher levels of understanding from kindergarten through secondary school. The major task is to make it possible for scientific and technological concepts to be enlarged in meaning at higher grade levels while fostering the continual growth of intellectual skills.

The development of alternative model curricula would set the stage for educators, textbook publishers and others to consider new instructional strategies and the creation of new science texts and other materials. The role of new textbooks in promoting improved science education was seen by the group as particularly important because it is so often the primary learning resource for students. Over the long term, the participants felt that individual textbooks might play a reduced role as supplementary materials become more available through computer information banks and the use of out-of-school sources. However, such a shift was seen as unlikely in the next few years.

Preservice Teacher Education

The national studies on the condition of education in America have emphasized the central role of teachers in bringing about improvements in schooling for the obvious reason that it is with teachers and students in the classroom that the improvement effort must finally manifest itself. In the case of the proposed change in direction of K-12 science education, the participants concluded that the focus on teachers is particularly important. In the group's view, a science/technology/society-oriented curriculum will require major changes in both preservice and inservice teacher education.

Concerning the preservice component, the participants felt it is necessary to recognize that teaching is an applied profession in the same sense as engineering, medicine, and law. There are bodies of knowledge and practice considered necessary for those entering these fields. More so in other countries than in the United States, precollege teaching is regarded as a professional field, and science teachers are trained in colleges or institutes where academic courses appropriate for teaching science are offered. For the most part, secondary school science teachers in the U.S. are trained in science departments that rarely make adjustments in courses that would make them more suitable to the educational goals precollege teachers must seek to achieve. Instead, prospective teachers take courses designed for aspiring scientists.

Moreover, the few required courses in pedagogy are not adequate in many schools of education. Typically, these courses constitute too little time (averaging only 25 semester hours of the prospective science teacher's 120 semester hours of coursework), do not have sufficient connection to the "real world of science teaching," and are often inadequately supported by their host institution. These courses also often tend to ignore the results of the growing knowledge base regarding both generic teaching skills and those associated with effective science teaching. This circumstance, in combination with the fact that many prospective secondary school teachers have a major in biology or chemistry, in which there may be little that can be applied directly to teaching high school life sciences or physical sciences, creates a major problem. The result is that "newly minted" science teachers in the United States often might be described best as half-trained researchers who are not well prepared to act as the interpreters of science and technology for the nation's young.

Beyond these current problems is the issue of how preservice programs need to be modified to prepare prospective teachers for a new curriculum with a substantial technological component. Although more than twelve hundred colleges and universities

now have courses or programs on science-technology-society, these offerings generally have been neither adapted to precollege teacher education programs nor required for certification. The participants believe that early attention needs to be given to the development of models for preservice teacher preparation which are based on the new science and technological literacy perspective.

In making these observations and recommendations regarding the improvement of preservice teacher education, the group was aware that it is now fashionable and easy to criticize schools of education. The participants recognized, however, that many problems associated with preservice preparation are to a considerable extent a function of circumstances beyond the control of these schools. For example, many needed improvements in teacher education would be costly to implement, and would depend in part on the ability of schools of education to attract a greater number of academically well-qualified students. Owing to the low pay and prestige of teaching, these are formidable structural obstacles to improvement. Nonetheless, because the participants believe that sound professional training is as necessary for teachers as for physicians, lawyers or business executives, they concluded that ways of overcoming these obstacles must be found soon.

Inservice Teacher Education

As important as reappraisal and reform of preservice science preparation are to the current school improvement effort, the meeting participants concluded that the inservice component is even more urgently in need of renewal. This is the case for several reasons:

(1) With continued declining enrollments at the middle school and high school levels in several areas of the country in the next few years, there will be few openings during this period for new science teachers in many districts.

(2) Experience has shown that most teachers, on their own, will not have the time, inclination, or resources to embrace new approaches to subject matter. Moreover, past inservice efforts have yielded

very disappointing results in terms of actually leading to substantial changes in how the average teacher conducts his or her class and how much students learn.

(3) The scientific and technological-literacy-for-all-students approach, if accepted, will lead to changes in the subject matter, curriculum content, and organizational format at all levels, K-12. This means that more teachers than in any previous reform effort would be in need of extensive and systematic inservice training on a sustained basis.

Given these circumstances, the participants believe that there are two pressing issues which educators and policymakers must address. First, effective inservice approaches must be identified and/or developed for the new approach to science education. Second, the question of how more extensive inservice training is to be paid for must be resolved. (Funds for inservice training are quite limited in most school districts.)

The Role of Teachers and Supervisors in Improving Science Education

The national reports on schools make it clear that any effort to reform science education must consider the process of change as well as the outcomes expected. Past experience with NSF-supported innovative science courses demonstrates that reform cannot be mandated, and that development of a new curriculum does not insure its proper implementation. Moreover, the research on curriculum implementation indicates that there is no proven model, no linear path, to curriculum reform in schools. Nonetheless, the participants believe that the evidence is clear that early and substantial involvement of school building-level educators is a key to bringing about real change.

In this regard, research has shown the pivotal role supervision plays in effecting lasting change. Principals and department heads influence or determine teaching schedules, equipment and text purchases, and tenure and promotion. First-line supervision is a powerful influence on what classroom teachers *do*. Thus, the informed support of supervisors is indis-

pensable to any significant change in content or teaching practice. Therefore, the participants concluded that representatives of the building-level supervisory groups should be integrally involved from the beginning in the planning of changes in science curriculum and classroom practice.

Equally if not more important, the group concluded that the proposed change in science curriculum must "begin" rather than "end" with teachers. This emphasis on early involvement of teachers recognizes the fact that it is the teacher who is the final arbiter of what is taught in the classroom, and how it is taught.

In the group's view, the participation of teachers means that they should be well represented in the planning and development phases of each area involved in the science education improvement effort. For example, any group charged with developing a new conceptual framework for science education should include experienced, practicing science teachers who have distinguished themselves in the classroom. Similarly, science teachers should be involved in the curriculum and materials development efforts. Later in the process, the science faculty of a particular school district or school should be deeply involved in the tailoring of the new curriculum to local circumstances and the demands of their individual classes.

Through such a participatory process, teachers would be given the absolutely necessary opportunity to engage in discussion of the rationale for proposed curricular and other changes as well as the chance to consider the supporting data and philosophical assumptions. They would also have an opportunity to demonstrate their professional "equality" with university-level science educators, practicing scientists and others.

Many observers of previous science education improvement efforts believe that a major reason why those efforts achieved much less than had been intended is that teachers and building-level administrators and supervisors were not full participants in the development process. The group concluded

that it is essential that this round of science education reform avoid that shortcoming.

Harnessing Educational Research

There is now an extensive body of educational research as well as practical experience that is relevant to a reform of science education. The research that has been done on child development, for example, provides a fair idea of whether children can master a certain scientific concept at a specific age range. Although teaching is frequently considered an "art," its scientific basis can be backed by a substantial amount of data. Therefore, the criticism that research on learning and teaching is not useful is incorrect. Part of the problem is that many teachers are not taught how, or given the opportunity to use, research findings to increase their effectiveness in the classroom. Much of what is known from research on learning and the use of knowledge also has tended to be neglected by curriculum developers and textbook authors.

If a comprehensive improvement in K-12 science education is to be achieved across the country, the meeting participants concluded that relevant educational research will finally have to be harnessed. For this to happen the group concluded that it will be necessary to:

(1) organize and synthesize the available research on science education, and rewrite it in terms useful to practitioners;

(2) develop mechanisms for continuously transmitting the findings of research to teachers, school administrators, policy-makers, teacher educators, and parents;

(3) integrate the research findings into preservice and inservice teacher education programs;

(4) encourage educational researchers to direct more of their attention toward solving educational problems of importance to teachers; and

(5) develop a systematic and ongoing analysis of educational research to determine gaps in what is known and what might be useful for advancing science education.

The number of people capable of synthesizing research results and/or translating academic research analysis into usable forms for practitioners is small. Consequently, there is a need to increase the number of these specialists.

Achieving the desired improvement in science education will doubtlessly entail added expense for the nation as a whole, as well as for individual school districts. Finding ways to use pertinent research could be one way to ensure not only that the desired improvement in science education will occur, but also that it will be achieved in a cost-effective way.

Organizing for Science Education Improvement

The initial efforts to bring about a major restructuring of science education along the lines being suggested really began around 1970. During the 1970s little visible progress was made toward either generating a broad awareness of the need for substantial changes, or actually implementing them. However, the large number of studies documenting the need for improvement that have appeared since 1980 have succeeded in focusing considerable national attention on the issue. The question now is whether this attention can be translated into action in the several areas discussed in previous sections of this report: the creation of a new conceptual framework for science education; the development of model courses and supporting instructional strategies and materials; the improvement of preservice and inservice teacher preparation programs; the early involvement of teachers and supervisors; and the harnessing of relevant educational research.

Ordinarily, it is assumed that local districts and schools will have primary responsibility for bringing about needed educational improvements for their students. Indeed, under the nation's decentralized approach to education, our nearly 16,000 school districts and approximately 80,000 schools have historically been a source of immense creativity and vitality. Nonetheless, on matters that require an unusually large commitment of financial resources and/or extensive analysis, most school districts must look outside for assistance. The current need

for fundamental science education improvement is clearly one of those matters requiring outside help.

As has been demonstrated by the early response to the several national reports, local districts can expect state governments to become involved. However, most seem likely to play a relatively limited role in promoting fundamental curricular and other changes. Similarly, the federal government can be of assistance, particularly financially. However, in our decentralized educational system the federal government does not have a mandate to provide central direction to a curricular change. (The group felt that this is probably as it should be.)

Several nongovernmental groups, including scientific and engineering societies, professional education associations, colleges and universities, as well as other elements of society (such as the business community), have expressed a willingness to be of assistance in the reform of science education. Nonetheless, their ability to be of help currently is limited for the following reasons:

(1) Each sees the reform from a limited point of view based on specific interests and partial data.

(2) There are few avenues of communication between the groups that make it possible to share ideas and data and to effect a dialog on the substantive issues.

(3) There is no mechanism or forum through which conflicting ideas can be mediated and policies shaped.

Under these circumstances the participants believe that it would be extremely desirable if some entity existed which could provide leadership and coordination for the science education improvement effort. Since in the group's view no existing organization appears to be in a position to assume this responsibility, the participants concluded that a new organization probably would need to be established.

The following are some of the essential capabilities that the group determined a new organization would have to possess to be effective within the nation's decentralized educational environment:

(1) the ability to marshall the mix of people essential for developing and legitimizing a conceptual framework for science education that can serve as a guide to nationwide educational programs and practices;

(2) the capability to encourage and/or assist efforts that individual districts cannot be expected to perform (e.g. development of model curricula, synthesis of relevant educational research, and identification of qualified consultants);

(3) the ability to work with state and local educators and to incorporate their several perspectives into the organization's work;

(4) the ability to enlist the cooperative efforts of key non-educational constituencies, such as scientists, engineers, and the business community; and

(5) the capacity to play a leadership/coordinating role in the reform movement for an extended period, recognizing the long-term nature of the tasks involved.

In order to function in the above manner, the participants concluded that the new organization probably would need to be a *consortium* with essentially two types of members:

(1) national educational organizations of the kind represented at the meeting; and

(2) the scientific and engineering professions.

Others, such as representatives from the business community, could be considered for membership, but the group felt that it might be better to enlist their cooperation as consultants rather than formal members. This is the case because the consortium's primary responsibility would be to serve the educational community in the area of science education improvement. To be effective, the consortium would have to avoid becoming too large and too diffuse in its constituency.

The group also believed that, to be successful, the consortium would need to be practical in outlook—emphasizing a pluralistic "what works" approach to helping foster desired change.

Properly structured, the new organization would hold the promise of providing high quality guidance and services for school districts across the country. Through a participatory process, the consortium could provide an opportunity to bring about something which has proved to be particularly difficult in this country: a common understanding of, and broad-based commitment to, an educational change of importance to all students and to the nation.

The participants concluded that the federal government might be the most appropriate source of seed money and core financing for such an enterprise. The private sector, foundations, individual school districts, state governments, and member organizations were seen as other sources of funding. The participants concluded that the consortium should initially do the following:

(1) undertake a full evaluation of the appropriateness of "scientific and technological literacy" for all students as a major new, unifying purpose for K-12 science education, and develop a supporting conceptual framework;

(2) facilitate development of a preliminary set of intellectual skills, concepts, and information about science and technology that should be mastered by all students during their K-12 years;

(3) encourage and assist in the development of model curricula that would provide coherent, articulated science education experiences during the K-12 years through which students could be realistically expected to acquire the knowledge and skills essential for scientific and technological literacy; and

(4) establish relationships with various sectors of society, including the news media, local/state/federal government, and the business community, that would help promote broad understanding of, and support for, the science education improvement effort.

The participants recognized that the characteristics and initial agenda sketched here for the new organization represent only one approach among many. Therefore, any effort designed to establish

such an organization should as a matter of course consider alternative approaches or options.

The participants also recognized that the consortial approach to educational improvement being suggested in this report is *unproven*. There is no consortium currently in existence designed to serve the nation's educational systems in the complex manner suggested here. Nonetheless, the need for leadership is substantial, while the existing alternatives for providing it are limited. For this reason the participants concluded that a consortial approach deserves early and full testing.

Science Education Improvement and the Non-Public Schools

The non public schools of America are important national resources, complements to local school districts, and often sources of innovation or reform. The non-public sector is itself diverse: residential schools; single-sex schools; religiously-oriented academies; and commuter prep schools. The oldest school in the U.S. is an "independent," the Collegiate School in New York City.

If our purpose is the reform of science education, then the ultimate justification is the benefit we expect to reap as a nation. The goal is a well-educated populace, irrespective of the schools from which they graduate. *All* schools must be involved.

Therefore, the group agreed that the independent or non-public school sector has an important role to play in designing and implementing reforms in science education.

The Context of Science Education Improvement

The participants recognized that science education is an integral, inseparable part of a complex system of courses, curricula programs, and requirements. Any significant change in one important component must affect the rest of the "organism." The sense of the participants was that science education improvement must take place without disrupting other core programs. Recognizing that educational

resources are relatively inelastic, the group believed that a combination of augmented resources and structural economies should be the first approach to obtaining the necessary funds.

Clearly, the details of the improvement strategy outlined here require careful study, but it is important that the much-needed reforms that the group proposes not be delayed unduly.

Appendix I

Meeting Attendees

Participants

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